

Impact of temporal gravity field parameters determined from GNSS satellites on the estimated Earth rotation parameters

Krzysztof Sośnica (1), Adrian Jäggi (1),
Rolf Dach (1), Daniela Thaller (2)

(1) Astronomical Institute, University of Bern, Switzerland

(2) Bundesamt für Kartographie und Geodäsie, Frankfurt am Main, Germany

IGS Workshop 2014 – Celebrating 20 Years of Service

June 23–27 2014, Pasadena, California, USA

Table of contents

Introduction:

- Motivation
- GNSS sensitivity to low-degree Earth's gravity field coefficients
- Solution set-up

Temporal Earth's gravity field from GNSS

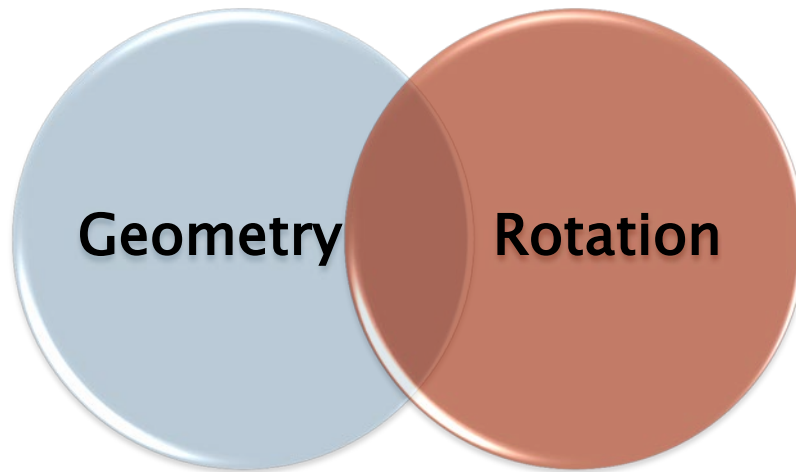
- C_{20} and correlation with dynamical orbit parameters
- Other low-degree coefficients

Earth Rotation Parameters (ERPs) & Geocenter

- Pole coordinates
- Pole rates
- Geocenter coordinates

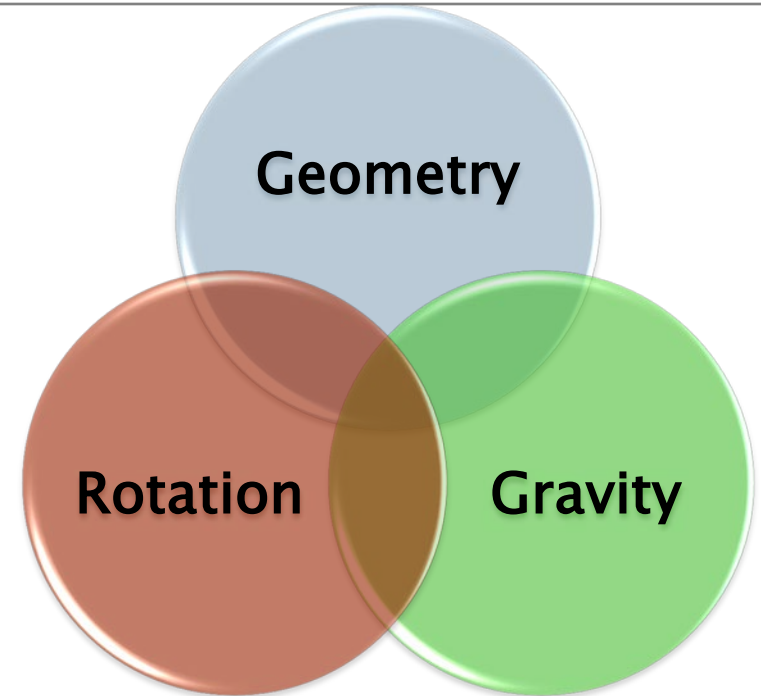
Conclusions

Three pillars of satellite geodesy



Current status:

IGS provides products related to **Geometry** and **Rotation**, but **not** to temporal variations in the Earth's **Gravity** field.



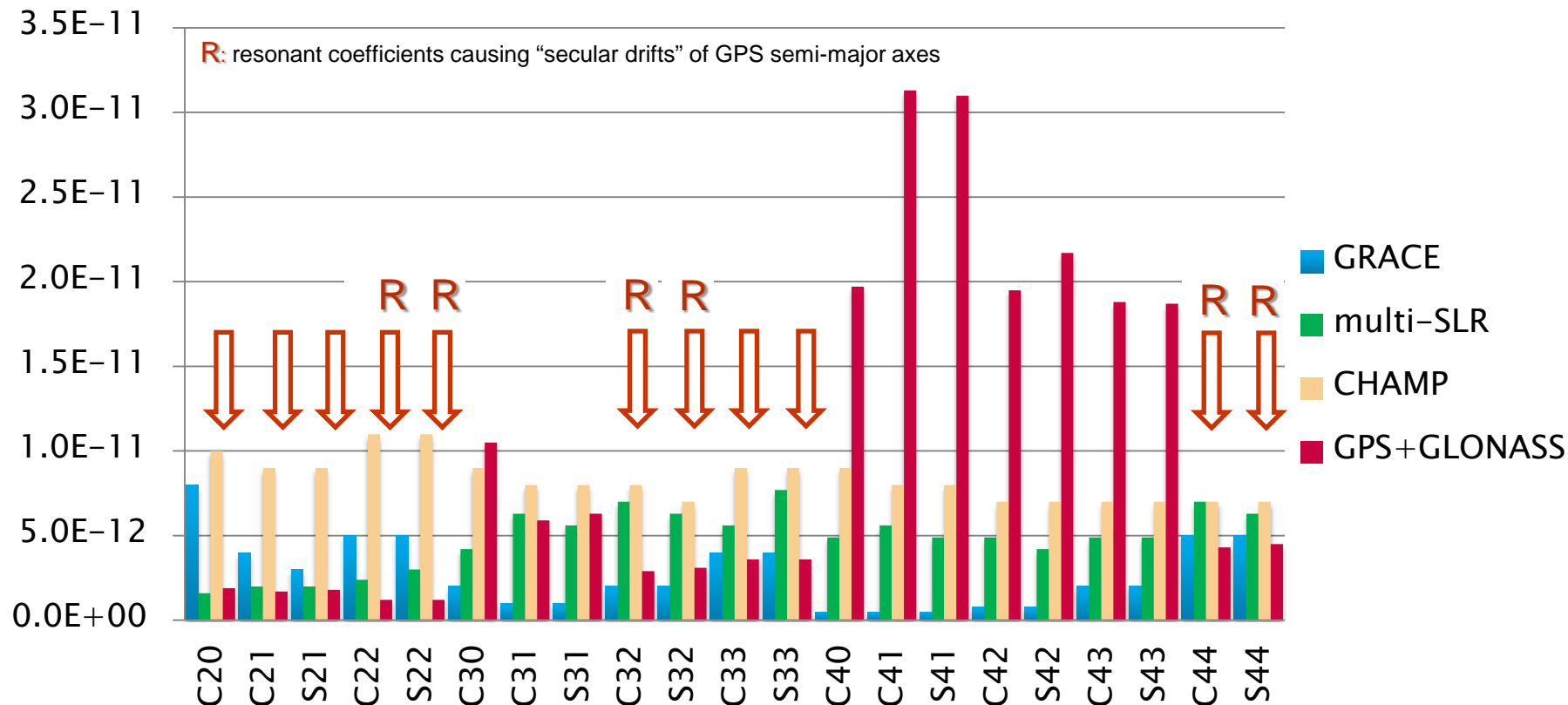
This solution:

Parameters related to **all three pillars** are simultaneously estimated, because they are strongly **dependent on each other**.

Are GNSS satellites sufficiently sensitive to variations of gravity?

Sensitivity of GNSS solutions to low-degree gravity coeff.

Mean a posteriori errors – monthly solutions



GNSS satellites are very sensitive to gravity field coefficients of **degree 2**. For coefficients above degree 3, GNSS are typically very sensitive only to **resonant gravity field coefficients**.

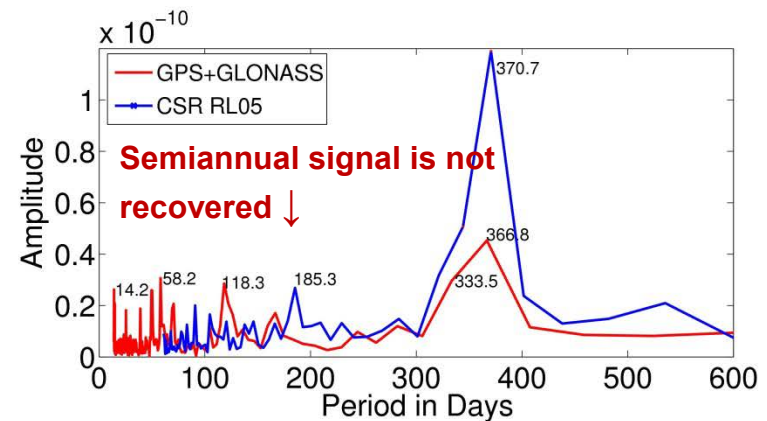
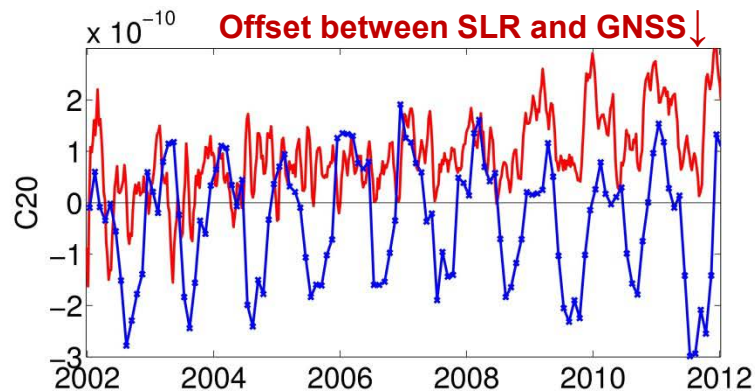
List of estimated parameters & solution set-up

Estimated parameters		GNSS solutions
		up to 32 GPS and 24 GLONASS satellites
Orbits	Osculating elements	$a, e, i, \Omega, \omega, u_0$ (1 set per 3 days)
	Dynamical parameters	D_0, Y_0, X_0, X_S, X_C – unconstrained D_S, D_C, Y_S, Y_C – constrained at 10^{-12} (1 set per 3 days)
	Pseudo-stochastic pulses	R, S, W (constrained, estimated every 12 ^h)
Earth rotation parameters		$X_P, Y_P, UT1-UTC$ (Piecewise linear, 1 set per day)
Geocenter coordinates		1 set per 7 days
Earth gravity field		Estimated up to d/o 4/4 (1 set per 7 days)
Station coordinates		1 set per 7 days
Other parameters		Troposphere ZD (2h), gradients (24h) and ZTD biases

We processed **10 years** of **GPS** and **GLONASS** data using the standard orbit modeling as from CODE with **two** major **exceptions**:

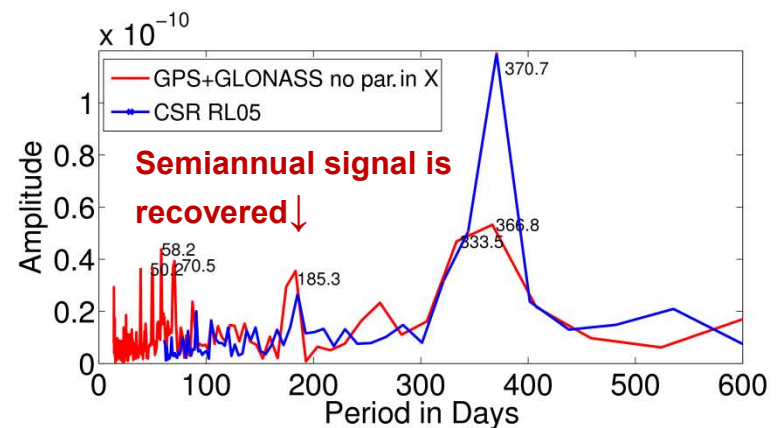
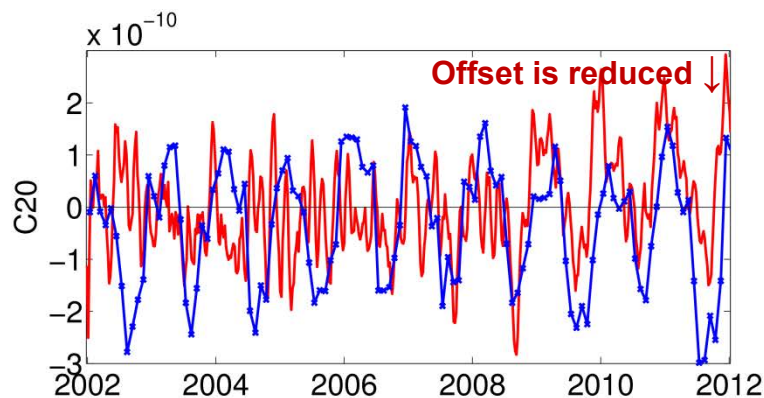
- **7-day solutions** are generated instead of the 3-day long-arc solutions as for the IGS.
- The Earth's **gravity field coefficients** up to **degree/order 4/4** and **geocenter** coordinates are simultaneously estimated along with other parameters.

C_{20} from GPS+GLONASS



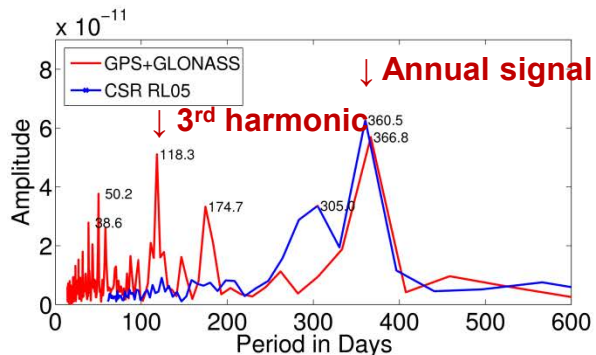
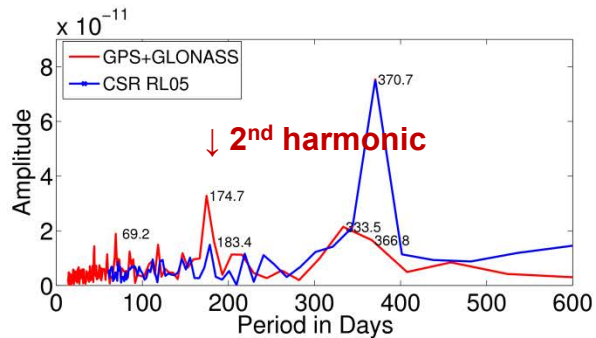
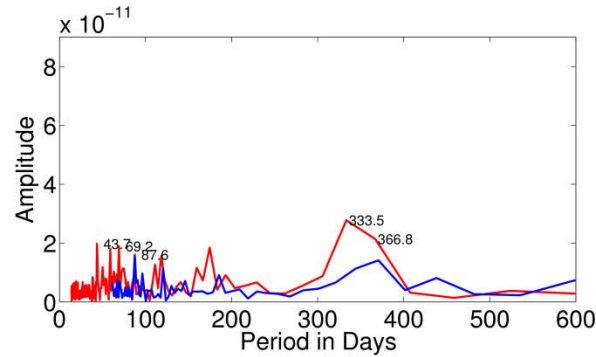
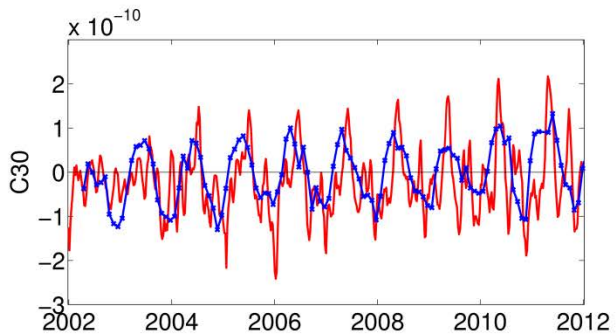
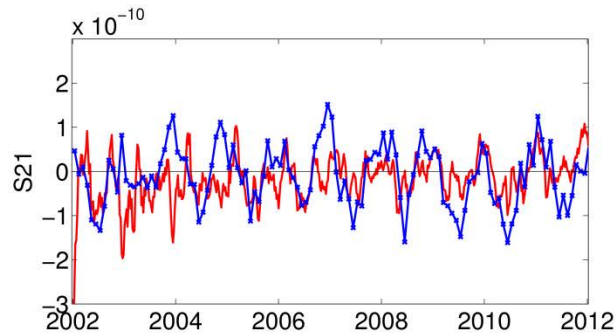
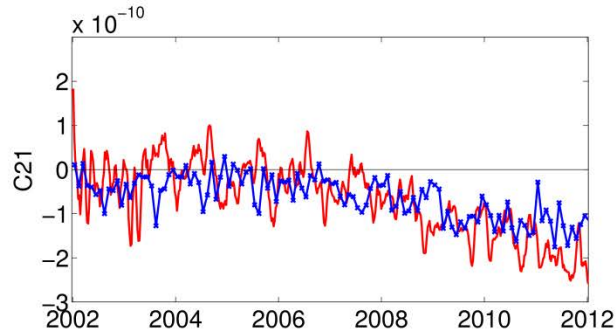
GNSS dynamic orbit parameters : D_0, Y_0, X_0, X_s, X_c

Orbit parameters in the X direction are correlated with C_{20}



GNSS dynamic orbit parameters : $D_0, Y_0, \cancel{X_0}, \cancel{X_s}, \cancel{X_c}$

C_{21} , S_{21} , C_{30} from GPS+GLONASS



GNSS-derived gravity field parameters agree quite well with the CSR RL05 results (median difference of $8.2 \cdot 10^{-11}$), but:

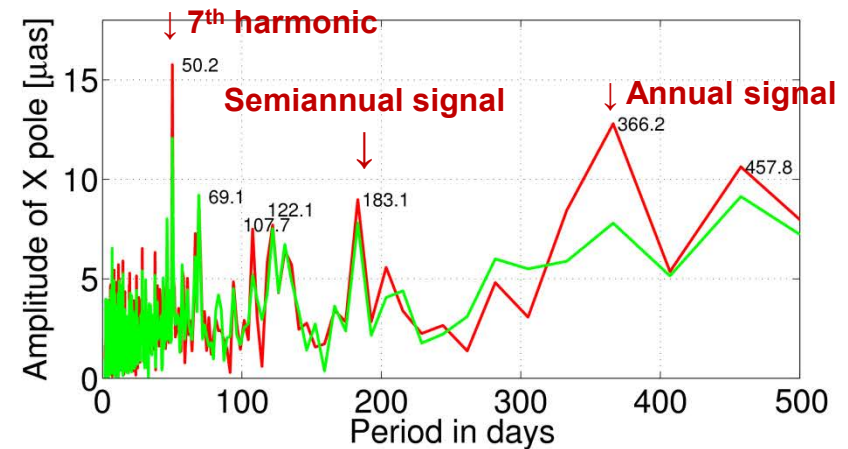
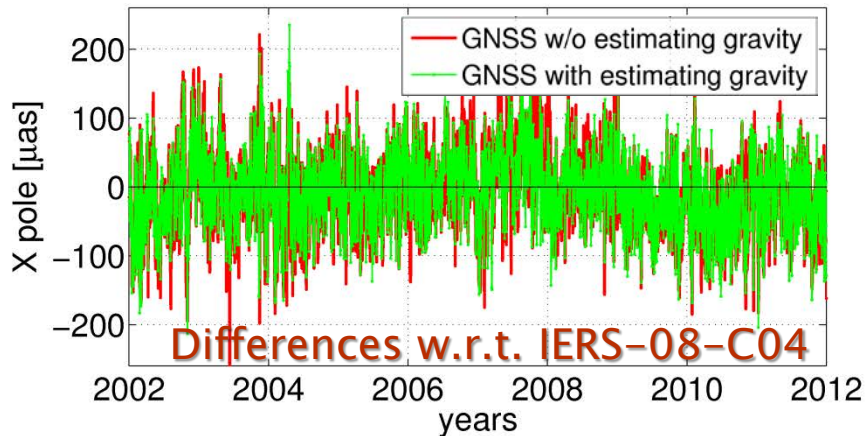
- GNSS-derived parameters show both: the **seasonal signals** as well as **draconitic periods**,
- C_{20} is **correlated** with orbit parameters in the **X** direction.

Gravity coefficients benefit from the contribution of **GLONASS** (after **2008**, when the station coverage improves).

Question:

How much affected are the **GNSS-derived parameters** by **neglecting** the temporal **gravity field variations**, since **GNSS satellites** are **sufficiently sensitive to recover** the temporal variations of Earth's low-degree **gravity field** ?

X- pole coordinate

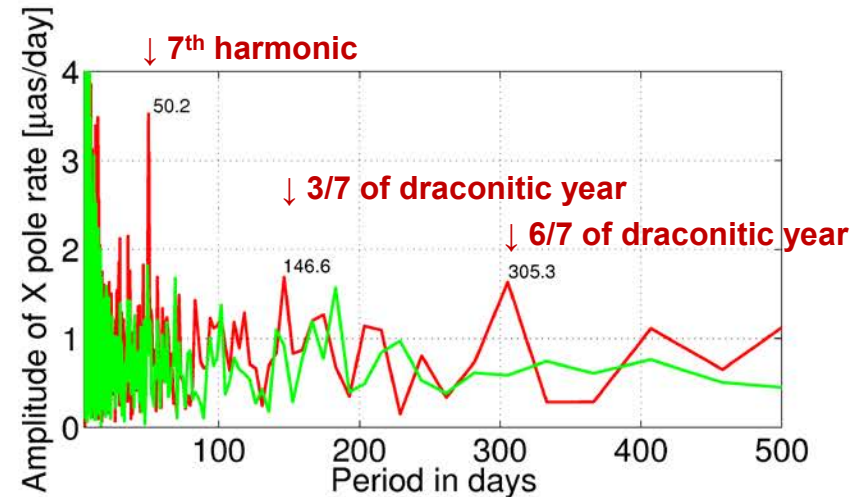
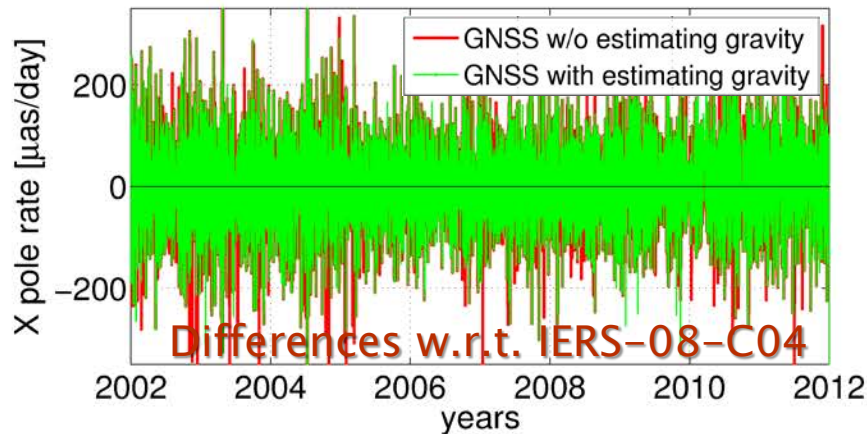


For the **X pole coordinate**:

- the amplitude of the 7th harmonic is reduced from **15.9** to **12.2** μs ,
- the amplitude of the annual signal is reduced from **12.8** to **6.9** μs ,
- the mean offset w.r.t. IERS-08-C04 is reduced from **-10.5** to **-9.9** μs ,

for the solutions **without** and **with estimating gravity field** parameters, respectively.

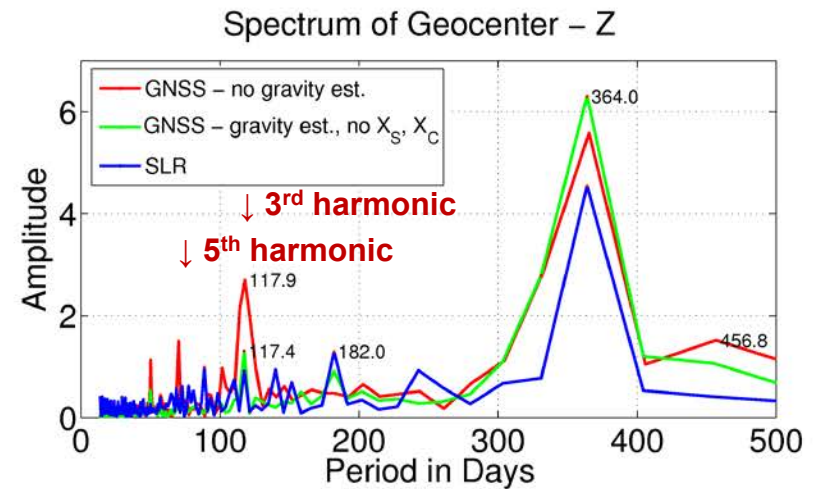
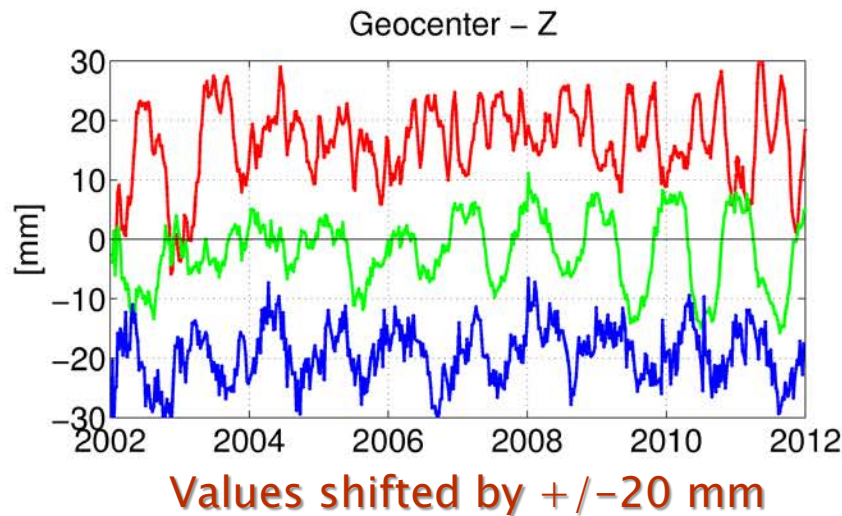
X- pole rate



For the **X pole rate**:

- the amplitude of the 7th harmonic is reduced from **3.5** to **1.8** μas/day,
 - the mean offset w.r.t. IERS-08-C04 is reduced from **2.2** to **2.0** μas/day,
- for the solutions **without** and **with estimating gravity field** parameters, respectively.

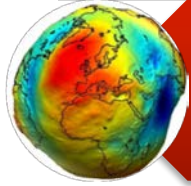
Z component of geocenter coordinates (C_{10})



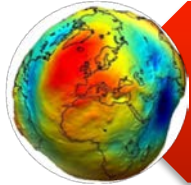
When **estimating the gravity field coefficients** and heavily constraining once-per-revolution orbit parameters in the X direction, the Z geocenter coordinate from **GNSS solutions (C_{10})**:

- is by far less affected by solar radiation pressure modeling,
 - is closer to the **SLR results**
- as compared to **GNSS solutions without estimating gravity field**.

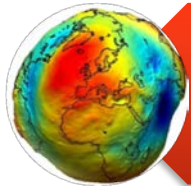
Summary



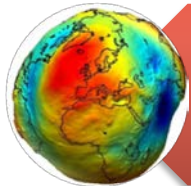
The GNSS satellites are sufficiently sensitive to low-degree gravity field parameters, to recover the temporal gravity field variations.



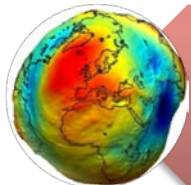
The simultaneous estimation of gravity field parameters along with ERPs, station coordinates, troposphere, and other GNSS parameters is feasible.



The empirical orbit parameters in the X direction are correlated with C_{20} , and thus, the X-parameters partly absorb the C_{20} variations. However, not all the gravity variations are absorbed by empirical parameters.



Unabsorbed gravity variations may contaminate the ERP estimates by introducing spurious peaks of seasonal and draconitic signals in the GNSS solutions when not estimating gravity field parameters.



Spurious seasonal and draconitic signals can be reduced by estimating the gravity field along with other GNSS parameters.



Thank you for your attention

IGS Workshop 2014 – Celebrating 20 Years of Service
June 23–27 2014, Pasadena, California, USA